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Evaluation of the effect of unilateral and bilateral inferior oblique myectomy on fundus torsion in primary and secondary inferior oblique overaction

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ABSTRACT

OBJECTIVE: This article evaluates the effects of unilateral and bilateral inferior oblique myectomy (IOM) on fundus torsion in primary and secondary inferior oblique overaction (IOOA).

METHODS: This study analyzed 230 OCT images of 53 eyes of 32 patients who had undergone IOM by a single surgeon in the last two years. The disc-foveal angle (DFA) was calculated by digitally measuring the angle between the horizontal line passing through the geometric center of the optic disc and the curved line connecting the fovea to the geometric center of the optic disc. DFA was classified into intorsion, normal torsion, and extortion. The DFA was measured from the OCT images before the operation in the first week, first month, third month, and sixth month.

RESULTS: When all the patients in our study were evaluated together, IOM statistically reduced the mean DFA in the third month (p=0.00). The DFA was higher in the secondary IOOA group than in the primary IOOA group (p=0.24). Bilateral IOM statistically significantly reduced DFA in the third month (p=0.00) and decreased the DFA difference between the two eyes in the third month (p=0.583). Unilateral IOM increased the DFA, rather than decreasing it, in the first week in operated eyes (p=0594) and increased the DFA difference between the two eyes after surgery (p=0.477). When we evaluated the localization of the macula as an intorsion, normal intorsion, or extortion, the extortion decreased from 36 to nine in the third month after bilateral IOM, and intorsion was seen in only two. Unilateral surgery did not significantly change fundus torsion in primary IOOA, and it caused intorsion in 3 of 6 (50%) operated eyes in secondary IOOA.

CONCLUSION: Although unilateral IOM provides a clinical improvement in secondary IOOA, it increases the difference in DFA between both eyes and causes intorsion in 50% of patients. Masked IOOA was detected in 3 of 11 (27.3%) patients who underwent unilateral IOM. When deciding on unilateral surgery, the possibility of increased DFA difference between both eyes, intorsion in the operated eye, and masked IOOA in the other eye should be considered.

Keywords: Bilateral inferior oblique myectomy; fundus torsion; primary inferior oblique overaction; secondary inferior oblique overaction; unilateral inferior oblique myectomy.

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Inferior oblique overaction (IOOA) causes fundus extortion due to the anatomical structure and function of the inferior muscle. The inferior oblique muscle externally rotates, elevates, and abducts the eye. The main task of the inferior oblique muscle is to elevate the eye in abduction. Inferior oblique overaction can be primary or secondary to superior oblique paralysis. The cause of primary IOOA is unknown, and secondary IOOA

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results from paresis or paralysis of the superior oblique muscle. Surgical treatment for IOOA includes recession, anterior transposition, anterior nasal transposition, and myectomy. These inferior oblique surgeries can be performed unilaterally or bilaterally to treat primary or secondary IOOA [1].

The measurement of DFA differs according to the method and person [2]. Many techniques, such as slit-lamp biomicroscopy, indirect ophthalmoscopy, conventional fundus photography, wide-field fundus photography, and optical coherence tomography, can measure macular localization and fundus torsion. Several recent studies have shown that OCT assessment of ocular torsion is as reliable as fundus photography [2–5]. Our study evaluated DFA with OCT because it is more valuable than fundus photography in younger children.

Fundus torsion is affected by many reasons, such as primary or secondary causes, unilateral or bilateral surgery, and recession, transposition, or myectomy surgical techniques. Many different publications in the literature show that unilateral and bilateral inferior oblique surgeries decrease DFA. To our knowledge, no studies have compared the effect of unilateral and bilateral IOM on fundus torsion. Our study investigated the impact of unilateral and bilateral IOM on fundus torsion in primary and secondary IOOA.

MATERIALS AND METHODS

This study analyzed 230 OCT images of 53 eyes of 32 patients who had undergone IOM by a single surgeon in the last two years. All eyes were imaged with OCT by Spectralis version 1.10.2.0 of Heidelberg Engineering. All measurements were taken by two people: a doctor and a technical staff member. Photographs of each eye were taken while both eyes were fixed on the camera's internal stabilization marker without being closed. While taking the OCT, care was taken so that the patient's head was not tilted to the right or left. The DFA was measured from the OCT images before the operation in the first week, first month, third month, and sixth month. The DFA was calculated by digitally measuring the angle between the horizontal line passing through the geometric center of the optic disc and the curved line connecting the fovea to the geometric center of the optic nerve disc. The DFA angle was measured digitally from the images using the Angle meter program (Fig. 1).

Highlight key points

- Bilateral IOM reduced the mean DFA and DFA differences between both eyes in all patient groups. Extortion decreased from 36 to 9 in the third month after bilateral IOM, and intorsion was seen in only two eyes.
- In secondary IOOA, unilateral IOM increases the DFA difference between the two eyes. Unilateral IOM caused intorsion in 3 of 6 (50%) operated eyes by overcorrection in patients with secondary IOOA. Masked IOOA was detected in 3 of 11 (27.3%) patients who underwent unilateral IOM.
- When deciding on unilateral surgery, the possibility of increased DFA difference between both eyes, intorsion in the operated eye, and masked IOOA in the other eye should be considered.

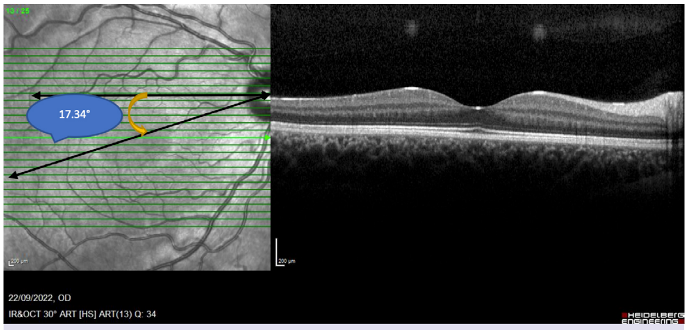

Figure 1. Digital calculation of DFA in OCT.

There is an angle value resulting from the DFA measurement, but it is necessary to interpret whether this value is normal or pathological. The results of our study were categorized according to the DFA values by Bixenman and von Noorden's method for practical interpretation. According to this classification, all DFA angles were classified into intorsion, normal torsion, and extortion (Fig. 2) [6]. It was considered intorsion if the macula was above the horizontal line passing through the geometric center of the optic disc. If the macula was below the horizontal line passing through the lower border of the optic disc, it was considered extortion. If the macula was located between the horizontal line passing through the optic disc geometric center and the horizontal line passing through the lower border of the optic disc, it was considered normal torsion (Fig. 3). The DFA above the horizontal line passing through the geometric center of the optic disc was calculated as negative (–) and below the DFA as positive (+). The difference in DFA was calculated between the two eyes. Inferior oblique overaction and superior paralysis in all patients were evaluated clinically in four grades.

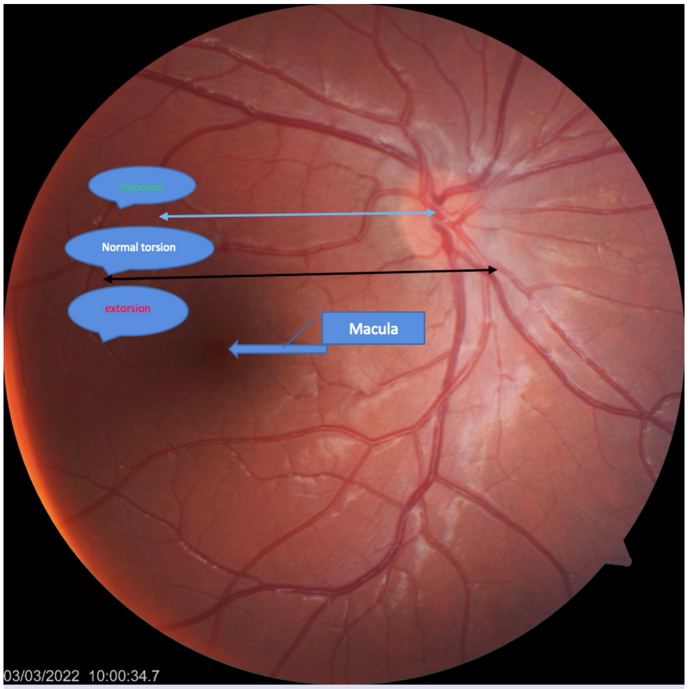

FIGURE 2. Evaluation of fundus torsion according to the Bixenman and von Noorden criteria (Yilmaz OF).

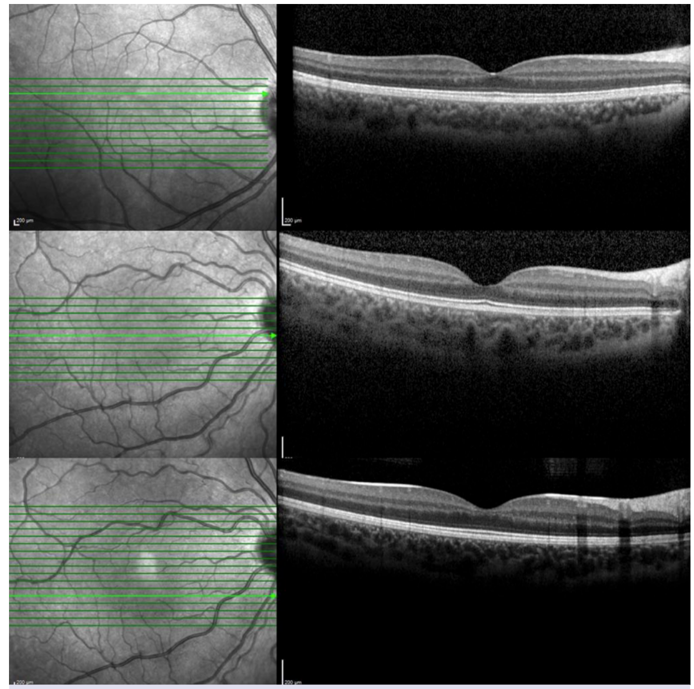

FIGURE 3. OCT images of intorsion (top photo), normal torsion (middle photo), and extortion (bottom photo). The fundus section must pass through the macula.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethics Committee of Istanbul Medeniyet University Goztepe Training and Research Hospital clinical research (decision number: 2022/0630, 02.11.2022) and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Inferior Oblique Myectomy Surgical Method

All surgeries were performed by a single surgeon using the fornix approach. Under general anesthesia, the conjunctiva and Tenon's capsule were dissected 8 mm away from the limbus in the inferior temporal region. After the inferior oblique muscle was fixed with a single hook, careful explorations were made across the globe to avoid missing the posterior fibers for complete muscle isolation. After the muscle was identified, an 8–10 mm section of the muscle was removed, and the muscle was released. The conjunctiva was closed with 8-0 polyglactin sutures.

Exclusion Criteria

In our study, only patients who underwent IOM were examined. Patients with inferior oblique recession or transposition were excluded from the study. Combined surgeries with IOM and horizontal rectus surgery were also not considered. Furthermore, patients with retinal diseases, previous strabismus surgery, retinal surgery, head trauma, or eyelid surgery were omitted from the study.

Statistical Analysis Methods

Frequency and percentages n (%) were used to define the categorical variables. The relationship between pre- and postoperative categorical data was examined using the parametric paired sample t-test and the nonparametric Wilcoxon signed-rank test, where appropriate. The chi-squared test examined the relationship between the primary and secondary IOOA groups and the unilateral and bilateral IOM groups. The statistical significance level was determined to be 0.05. Analyses were performed using MedCalc Statistical Software version 19.7.2 (MedCalc Software Ltd., Ostend, Belgium; https://www.medcalc.org; 2021).

RESULTS

Our study evaluated 230 oct images of 64 eyes of 32 patients who underwent IOM by a single surgeon during a 6-month follow-up. Statistical evaluation was carried out until the months when the number of OCT images was

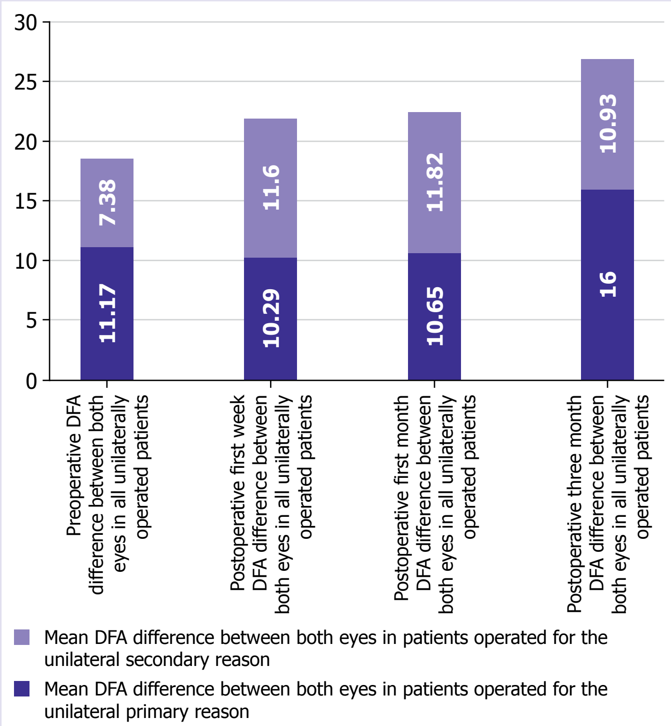

Figure 4. Mean DFA difference between both eyes in unilaterally operated patients.

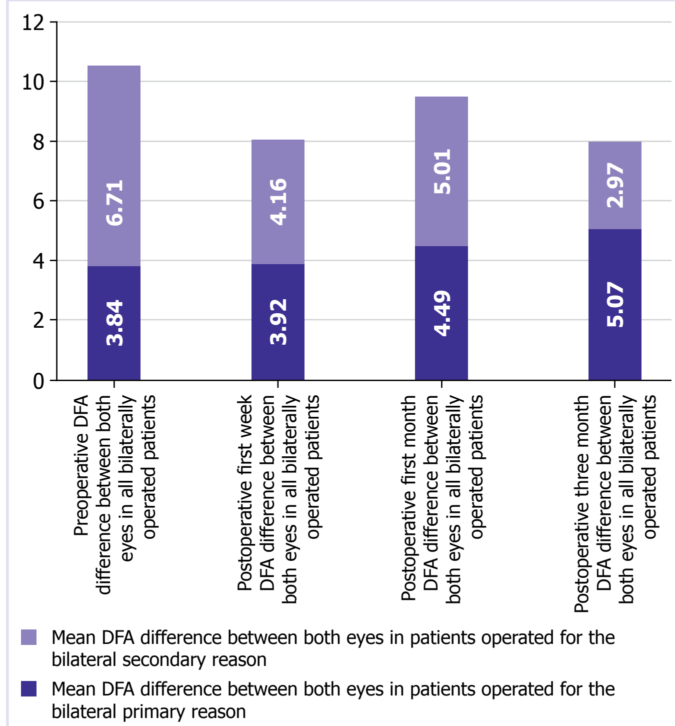

Figure 5. Mean DFA difference between both eyes in bilaterally operated patients.

sufficient. All measurements were made by two people: a doctor and a technical staff member. According to Lin's concordance correlation coefficient, measurements made by two different people were found to be statistically correlated (p>0.05). The mean age of the 32 patients was 10.7±9.2 years (4–42). The mean DFA of both eyes of 32 patients with IOOA was preoperatively 14.54°; the postoperative DFAs were: first week 4.71°, first month 7.56°, and third month 7.69°. When all the patients in our study were evaluated together, IOM statistically reduced the mean DFA third month (p=0.00) (Table 1).

In 11 patients with unilateral IOOA, the mean DFA in the hyperfunction eyes was 8.35°, while the DFA angle in the non-hyperfunctioning eyes was 14.88° (Table 1). The DFA angle was higher in the non-hyperfunctional eye than in the hyper-functional eye (p=0.232). Thirteen patients were operated on for primary IOOA, and 19 patients were operated on for secondary IOOA. The preoperative mean DFA was 12.64° in patients with primary IOOA and 15.85° in patients with secondary IOOA. The DFA was higher in the secondary IOOA than in the primary IOOA (p=0.24).

In unilaterally operated patients, the preoperative DFA in the operated eye was 8.35°, 11.54° in the first week, and 6.06° in the first month. Unilateral IOM increased DFA rather than decreased in the first week in the operated eyes (p=0594). Unilateral IOM decreased DFA in the first month in the operated eyes. In the non-operated fellow eyes of unilaterally performed patients, the mean DFA was 14.88° preoperatively, 11.54° in the post-op first week, 12.96° in the post-op first month, and 15.88° in the post-op third month. The mean DFA increased in the third month in fellow non-operated eyes (p=0.655). The mean DFA values of both eyes of 21 patients who were operated on bilaterally were 16.07° preop, 3.40° in the first week of surgery, 6.59° in the first month, and 6.60° in the third month (Table 1). Bilateral IOM statistically significantly reduced DFA in third month (p=0.00).

The DFA difference between the two eyes in bilateral IOM was 18.11° preoperatively, 9.50° in the first week, 9.45° in the first month, and 8.00° in the third month. Bilateral IOM decreased the DFA difference between the two eyes in third month (p=0.583). The DFA difference between the two eyes in unilateral IOM was 9.19° preoperatively, 10.46° in the post-op first week, and 10.49° in the first month. Unilateral IOM increased the DFA difference between the two eyes after surgery

TABLE 1. Preoperative, postoperative 1st-week, 1st-month, and 3rd-month DFA values

	Preop DFA	Postoperative 1-week DFA	Postoperative 1-month DFA	Postoperative 3-month DFA
Unilateral operated eye (n=11)				
Primer (n=5)	**9.89°±6.21°** (*+4,23°*, **+20°**)	*7.35°±5.37°* (*+3°*, **+14°**)	**10.14°±6.52°** (*+2°*, **+17,22°**)	**8.4°±4.8°** (*+5°*, **+11.8°**)
Seconder (n=6)	*7.07°±2.84°* (*+4°*, **+12.14°**)	***-0.83°±4.91°*** (***-7***, *+7°*)	*2.80°±5.5°* (***-5***, *+7.44°*)	*2.80°±5.5°* (***-3***, *+7.44°*)
Total (n=11)	**8.35°°±4.65°** (*+4°*, **+20°**)	*3.34°±4.65°* (***-7°***, **+14°**)	*6.06°±6.78°* (***-5°***, **+17.22°**)	*3.55°±5°* (***-3°***, **+11.8°**)
Unilateral non-operated eye (n=11)				
Primer (n=5)	**15.81°°±12.65°** (*+2°*, **+28.42°**)	**13.24°°±8.0°** (*+5°*, **+22°**)	**15.65°°±9.9°** (*+4.7°*, **+24°**)	**24.2°±7.36° (+19°, +29.41°)**
Seconder (n=6)	**14.11°±7.45°** (*+6.53°*, **+26.7°**)	**10.11°°±6.73°** (*+3°*, **+20.38°**)	**11.35°±6.08°** (*+2°*, **+18.42°**)	**12.55°±3.41° (+9.2°, +18.12°)**
Total (n=11)	**14.88°°±9.62°** (*+2°*, **+28.42°**)	**11.54°±7.14°** (*+3°*, **+22°**)	**12.96°±7.35°** (*+2°*, **+24°**)	**15.88°±7.0° (+9.2°, +29.41°)**
Unilateral both eyes (n=22)				
Primer (n=10)	**12.85°±9.90°** (*+2°*, **+28.42°**)	**10.30°±7.14°** (*+3°*, **+20.38°**)	**12.56°±7.33°** (*+2°*, **+24°**)	**16.3°±10.44°** (*+5°*, **+29.41°**)
Seconder (n=12)	**10.59°±6.51°** (*+4°*, **+26.70°**)	*4.64°±8.02°* (***-7°***, **+22°**)	*7.08°±7.08°* (***-5°***, **+18.42°**)	*7.08°±6.72°* (***-3°***, **+18.12°**)
Total (n=22)	**11.62°°±8.1°** (*+2°*, **+28.2°**)	**11.54°±6.97°** (*+3°*, **+22°**)	**9.31°±7.7°** (***-3°***, **+22°**)	**9.72°±8.66°** (***-3°***, **+29.41°**)
Bilateral operated eye (n=42)				
Primer (n=14)	**12.88°±6.45° (+4°, +23°)**	*2.17°±4.95°* (***-6°***, **+11.21°**)	*4.89°±5.02°* (***-5°***, **+13°**)	*3.25°±4.43°* (***-3°***, **+11.1°**)
Seconder (n=28)	**17.67°±7.81° (+2°, +32°)**	*4.01°±4.91°* (***-5°***, **+17°**)	*7.67°±6.54°* (*-3°*, **+20.52°**)	**8.7°±6.03°** (*+0.51°*, **+18.47°**)
Total (n=42)	**16.07°°±87.65° (+2°, +32°)**	*3.40°±4.94°* (***-6°***, **+17°**)	*6.59°±6.08°* (***-5°***, **+20.52°**)	*6.6°±6.02°* (***-3°***, **+18.47°**)
Total (n=64 eyes)	**14.54°±8.03°** (*+2°*, **+32°**)	*4.71°±6.36°* (***-7°***, **+22°**)	*7.56°±6.67°* (***-5°***, **+24°**)	*7.69°±7.11°* (***-3°***, **+29.41°**)

Bold: Extortion; Bold italic: Intorsion; Italic: Normal torsion; DFA: Disc-foveal angle.

TABLE 2. DFA difference between both eyes in unilateral and bilateral eyes

	Preop DFA difference between two eyes	Postoperative 1-week DFA difference between two eyes	Postoperative 1-month DFA difference between two eyes	Postoperative 3-month DFA difference between two eyes
Unilateral operated patients (n=11)				
Primer (n=10)	11.17°±6,69° (6°, 22.42°)	10.29°±6.16° (3.36°, 16.38°)	10.65°±7.79° (4.22°, 22°)	16°±2.82° (14, 18°)
Seconder (n=12)	7.38°±8° (0.8°, 21.60°)	11.6°±8.32° (2°, 25°)	10.82°±7.37° (5.44°, 23.42°)	10.93°±2.52° (7.17°, 14°)
Bilateral operated patients (n=22)				
Primer (n=14)	3.84°±3.72° (0.18°, 7.9°)	3.92°±3.85° (0°, 9.5°)	4.49°±2.25° (1.3°, 8.5°)	5.7°±2° (3°, 8°)
Seconder (n=28)	6.71°±5.4° (0.22°, 18.11°)	4.16°±2.18° (1°, 8.3°)	5.01°±3.25° (0.18°, 9.45°)	2.97°±2.16° (0°, 6°)

DFA: Disc-foveal angle.

(p=0.477). The preoperative DFA difference was 7.38° in the secondary unilateral IOM eyes, 11.6° in the first week, 10.82° in the first month, and 10.93° in the third month. Unilateral IOM increased the DFA difference between both eyes in the third month (p=0.075) (Fig. 4). Additionally, unilateral IOM caused macular intorsion by overcorrecting the operated eye in 3 of 6 (50%) patients with secondary IOOA. The preoperative DFA difference was 6.71° in secondary bilateral IOM eyes, 4.16° in the first week, 5.01° in the first month, and 2.97° in the third month (Table 2). Bilateral IOM reduced the DFA between both eyes (p=0.74) (Fig. 5).

We evaluated macular torsion in our study as normal torsion, extortion, or intorsion, according to the Bixenman and von Noorden criteria. Extortion in 50 eyes (78.2%) and normal torsion in 14 eyes (21.8%) were found in the preoperative examinations of all patients. Extortion was seen in 15 eyes (38.5%) and intorsion in 4 eyes (10.3%) in the post-op third month. Extortion decreased from 36 to 9 in the third month after bilateral IOM, and intorsion was seen in only 2. Unilateral surgery did not significantly change fundus torsion in primary IOOA, and it caused intorsion in 3 of 6 (50%) operated eyes in secondary IOOA (Table 3).

DISCUSSION

It is known that IOOA causes fundus extortion. Many studies have shown that unilateral superior oblique paralysis (SOP) causes extortion in both eyes [7]. In unilateral SOP, extortion may be in the paretic, nonparetic, or bilateral eyes. In the literature, congenital unilateral SOP has been shown to cause higher fundus torsion than is acquired. Kim et al. [8] showed that fundus torsion in congenital unilateral SOP is more common in nonparetic eyes. In the study by Kim et al. [8], 61.1% of congenital unilateral SOP patients and 46.5% of acquired USOP patients showed extortion in both eyes. In studies by Kim et al. and Wang et al. [8, 9] on patients with congenital SOP, more extorsion was found in nonparetic eyes. In our study, the DFA angle was higher in the non-paretic eye in patients with unilateral IOOA compared to the paretic eye.

Many methods have been described in the past for measuring DFA. Several subjective methods evaluate ocular torsions, such as slit-lamp biomicroscopy, Bagolini glasses, the double Maddox rod test, indirect ophthalmoscopic lens, perimetry, and synoptophore. In 1982, Bixenman et al. [6] objectively evaluated the anatomical angle between the optic disc and the macula with fundus photographs. In this study, the macula was located between the horizontal line passing through the geometric center of the optic disc and the horizontal line passing through the lower edge of the optic disc. In the measurements made by fundus photography of 50 people without strabismus, the fovea was located 7.25° (0.3-disc diameter) below the horizontal line passing through the optic nerve center. The mean DFA between both eyes in the healthy subjects was 1.61°. In the study performed with OCT in 2020, the right DFA was found to be 5.27±2.67°, and the left DFA was 5.72±3.20° in 85 normal healthy individuals [2].

In many studies, IOM has been shown to reduce DFA, but we could not find a study comparing unilateral and bilateral IOM. In our research, IOM decreased the mean DFA when all patients were evaluated together. However, reducing the DFA value does not mean that the macula has returned to its normal position. Jinho Lee et al. [10] showed that inferior oblique surgeries reduce DFA. Ahmed Awadein et al. [11] performed symmetrical IOM in bilateral asymmetric IOOA. In the 6-month follow-up, no patient developed inferior oblique underaction or an A-V pattern. Although the mean inferior oblique surgery reduced the averaging DFA value in these studies, fundus extortion continued in some patients. Awadein et al. [11] found that in the presence of asymmetric IOOA, bilateral symmetric IOM surgery can have a "symmetrizing" effect on IOOA.

Few studies in the literature have investigated the effects of unilateral inferior oblique surgeries on fundus torsion. These studies have shown that unilateral inferior oblique surgeries reduce the mean DFA. A study conducted with 60 patients with SOP in 2020 demonstrated that unilateral IOM decreased the mean bilateral DFA [9]. Similarly, in our research, unilateral IOM decreased the mean DFA in SOP, but unilateral IOM caused intorsion due to overcorrection in 3 of 6 (50%) patients in secondary IOOA (Table 2). Additionally, the DFA difference between both eyes increased in unilaterally operated with secondary IOOA (Table 3).

Lee et al. [12] compared the excyclotorsion effect of the inferior oblique recession in 78 eyes of 78 patients with primary and secondary IOOA. In this study, the preoperative mean DFA was significantly greater in secondary than in primary IOOA, and a significant reduction in torsion angle occurred in both types after IO regression. The degree of DFA correction was numerically

TABLE 3. Preoperative, postoperative 1st-week, 1st-month, and 3rd-month fundus torsion evaluation according to Bixenman and von Noorden's criteria

	Preoperative	Postoperative 1-week	Postoperative 1-month	Postoperative 3-month	Postoperative 6-month
Unilateral operated eye (n=11) Primer (n=5)	**3 eyes extortion**, *2 eyes normal torsion (n=5)*	**2 eyes extortion**, *3 eyes normal torsion (n=5)*	**3 eyes extortion**, *1 eye normal torsion (n=4)*	**1 eyes extortion**, *1 eyes normal torsion (n=2)*	**2 eyes extortion**, *1 eyes normal torsion (n=3)*
Seconder (n=6)	**3 eyes extortion**, *3 eyes normal torsion (n=6)*	***3 eyes intorsion,*** *3 eyes normal torsion (n=6)*	***2 eyes intorsion,*** *3 eyes normal torsion (n=5)*	***2 eyes intorsion,*** *3 eyes normal torsion (n=5)*	*1 normal torsion (n=1)*
Total (n=11)	**6 eyes extortion**, *5 eyes have normal torsion (n=11)*	**2 eyes extortion**, ***3 eyes intorsion,*** *6 eyes normal torsion (n=11)*	**3 eyes extortion**, ***2 eyes intorsion,*** *4 eyes normal torsion (n=9)*	**1 eyes extortion**, ***2 eyes intorsion,*** *4 eyes normal torsion (n=7)*	**2 eyes extortion**, ***1 eyes intorsion,*** *1 eye normal torsion (n=4)*
Unilateral non-operated eye (n=11) Primer (n=5)	**3 eyes extortion**, *2 eyes normal torsion (n=5)*	**3 eyes extortion**, *2 eyes normal torsion (n=5)*	**3 eyes extortion**, *1 eye normal torsion (n=4)*	**1 eyes extortion**, *1 eye normal torsion (n=2)*	**3 eyes extortion** *(n=3)*
Seconder (n=6)	**5 eyes extortion**, *1 eye normal torsion (n=6)*	**3 eyes extortion**, *3 eyes normal torsion (n=6)*	**4 eyes extortion**, *1 eye normal torsion (n=5)*	**4 eyes extortion**, *1 eye normal torsion (n=5)*	*1 eye normal torsion (n=1)*
Total (n=11)	**8 eyes extortion**, *3 eyes normal torsion (n=11)*	**6 eyes extortion**, *5 eyes normal torsion (n=11)*	**7 eyes extortion**, *2 eyes normal torsion (n=9)*	**5 eyes extortion,** *2 eyes normal torsion (n=7)*	**3 eyes extortion**, *1 eye normal torsion (n=4)*
Unilateral both eyes (n=22) Primer (n=10)	**6 eyes extortion**, *4 eyes normal torsion (n=10)*	**5 eyes extortion**, *5 eyes normal torsion (n=10)*	**6 eyes extortion**, *2 eyes normal torsion (n=8)*	**2 eyes extortion**, *2 eyes normal torsion (n=4)*	**5 eyes extortion**, *1 eye normal torsion (n=6)*
Seconder (n=12)	**8 eyes extortion**, *4 normal eye torsion (n=12)*	**3 eyes extortion**, ***3 eyes intorsion*** *6 eyes normal torsion (n=12)*	**4 eyes extortion**, ***2 eyes intorsion*** *4 eyes normal torsion (n=10)*	**4 eyes extortion**, ***2 eyes intorsion*** *4 eyes normal torsion (n=10)*	*2 eyes normal torsion (n=2)*
Total (n=22)	**14 eyes extortion**, *8 normal eye torsion (n=22)*	**8 eyes extortion**, ***3 eyes intorsion*** *11 eyes normal torsion (n=22)*	**10 eyes extortion**, ***2 eyes intorsion*** *6 eyes normal torsion (n=18)*	**6 eyes extortion**, ***2 eyes intorsion*** *6 eyes normal torsion (n=14)*	**5 eyes extortion**, *3 eyes normal torsion (n=8)*
Bilateral operated eye (n=42) Primer (n=14)	**11 eyes extortion**, *3 normal eye torsion (n=14)*	**2 eyes extortion**, ***4 eyes intorsion*** *8 eyes normal torsion (n=14)*	**3 eyes extortion**, ***1 eyes intorsion*** *6 eyes normal torsion (n=10)*	**2 eyes extortion**, ***2 eyes intorsion*** *6 eyes normal torsion (n=10)*	**1 eyes extortion**, *3 eyes normal torsion (n=4)*
Seconder (n=28)	**25 eyes extortion**, *3 eyes normal torsion (n=28)*	**5 eyes extortion**, ***4 eyes intorsion*** *19 eyes normal torsion (n=28)*	**8 eyes extortion**, ***2 eyes intorsion*** *12 eyes normal torsion (n=22)*	**7 eyes extortion**, *9 eyes normal torsion (n=16)*	*(n=0)*
Total (n=42)	**36 eyes extortion**, *6 eyes normal torsion (n=42)*	**7 eyes extortion**, ***8 eyes intorsion*** *27 eyes normal torsion (n=42)*	**11 eyes extortion**, ***3 eyes intorsion*** *18 eyes normal torsion (n=32)*	**9 eyes extortion**, ***2 eyes intorsion*** *15 eyes normal torsion (n=26)*	**1 eyes extortion**, *3 eyes normal torsion (n=4)*
Total (n=64 eyes)	**50 eyes extortion**, *14 eyes normal torsion (n=64)*	**15 eyes extortion**, ***11 eyes intorsion,*** *38 eyes normal torsion (n=64)*	**21 eyes extortion**, ***5 eyes intorsion,*** *24 eyes normal torsion (n=50)*	**15 eyes extortion**, ***4 eyes intorsion,*** *21 eyes normal torsion (n=40)*	**6 eyes extortion**, *6 eyes normal torsion (n=12)*

Bold: Extortion; Bold italic: Intorsion; Italic: Normal torsion.

Table 4. Comparison of the results of the studies in the literature with the results of our study

Results of studies in the literature	The results of our study
In a study by Kim et al. [8], 61.1% of congenital unilateral SOP patients and 46.5% of acquired unilateral SOP patients showed extortion in both eyes. In a study by Wang et al. [9], extortion was found more in nonparetic eyes in patients with congenital unilateral SOP.	The DFA angle was higher in the non-paretic eye in patients with unilateral IOOA compared to the paretic eye.
Lee et al. [10] showed that inferior oblique surgeries reduced DFA. Wang et al. [9] showed that unilateral IOM reduced the mean bilateral DFA in 60 patients with SOP. Awadein et al.4 found that in the presence of asymmetric IOOA, bilateral symmetric IOM surgery can have a "symmetrizing" effect on IOOA. Although the IOM decreased the mean DFA value in these studies, some patients continued to have fundus extortion.	In our research, IOM decreased the mean DFA when all patients were evaluated together. However, reducing the DFA value does not mean that the macula has returned to its normal position. Bilateral IOM reduced the mean DFA and DFA differences between both eyes in all patient groups. In secondary IOOA, unilateral IOM increases the DFA difference between the two eyes. Unilateral IOM caused intorsion in 3 of 6 (50%) operated eyes by overcorrection in patients with secondary IOOA.
Lee et al. [12] compared the effect of IOM on fundus position in 78 eyes of 78 patients with primary and secondary IOOA. Preoperative mean DFA was significantly higher in secondary IOOA than in primary IOOA. The reduction in the DFA angle after IOM was found to be higher in secondary IOOA. This study did not investigate whether the macula returned to its normal position and did not compare unilateral versus bilateral surgeries.	In our study, the secondary cause was more fundus torsion in the primary IOOA. Unilateral IOM did not significantly change DFA in primary IOOA; it caused intorsion due to overcorrection in 3 of 6 (50%) secondary IOOA patients.
Roh et al. [13] detected objective torsion in all patients with unilateral superior oblique muscle palsy, and they could not see subjective torsion in some. Kim et al. [14] showed that ocular torsion could be reduced in the visual sighting dominant eye in patients with unilateral congenital superior oblique paralysis. Mai et al. [15] investigated the effects of inferior oblique weakening surgeries on subjective and objective ocular torsion. Although they detected a decrease in DFA after surgery, they could not find a relationship between changes in subjective and objective cyclodeviations.	Our study detected extortion or intorsion in patients without IOOA in the postoperative period. This result shows that there is no relationship between the IOOA degree and DFA. Additionally, our study observed that the eye with a predominant objective macular extortion changed in a few patients under follow-up. This result shows that the degree of macular torsion will decrease in the fixated eye due to alternation, while it may increase in the unfixed eye.
Unilateral IOM may reveal a masked IOOA in the fellow eye. The average masked IOOA rate in the fellow eye is 37%. [16]	Inferior oblique overaction was detected postoperatively in two of 21 (9.5%) patients with bilateral IOM and 4 of 11 (36.3%) with unilateral IOM. Masked IOOA was seen in 3 of 11 (27.3%) patients who underwent unilateral IOM.

SOP: Superior oblique paralysis; DFA: Disc-foveal angle; IOM: Inferior oblique myectomy; IOOA: Inferior oblique overaction.

more critical in the secondary IOOA compared to the primary IOOA. However, this study did not investigate whether the macula returned to its normal position, and unilateral versus bilateral surgery was not compared. In our study, the secondary IOOA causes more fundus torsion than primary IOOA. Unilateral IOM did not significantly change DFA in primary IOOA, but it caused intorsion due to overcorrection in 3 of 6 (50%) secondary IOOA patients (Table 4).

In the literature, no relationship was found between objective and subjective torsion. While Roh et al. [13] detected objective torsion in all patients with unilateral superior oblique muscle palsy, they could not see subjective torsion in some patients. In another study, Kim et al. [14] showed that ocular torsion could be reduced in the visual sighting dominant eye in patients with unilateral congenital superior oblique paralysis. Mai et al. [15] investigated the effects of inferior oblique weakening surgeries on subjective and objective ocular torsion in 40 eyes of 20 patients. Although they detected a decrease in DFA after surgery, they could not find a relationship between changes in subjective and objective cyclodeviations. Our study detected extortion or intorsion in patients without IOOA in the postoperative period. This result shows that there is no relationship between IOOA degree and DFA. Additionally, our study observed that the eye with a predominant objective macular extortion changed in a few patients under follow-up. This result shows that the degree of macular torsion will decrease in the fixated eye due to alternation, while it may increase in the unfixed eye (Table 4).

Unilateral IOM may reveal a masked IOOA in the fellow eye. The average masked IOOA rate in the fellow eye is 37%.16 In our study, IOOA was detected postoperatively in two of 21 (9.5%) patients with bilateral IOM and 4 of 11 (36.3%) with unilateral IOM. In our research, masked IOOA was seen in 3 of 11 (27.3%) patients who underwent unilateral IOM. In one of our patients with unilateral grade +4 IOOA and exotropia 6 months after unilateral IOM surgery and bilateral lateral rectus regression, +4 IOOA was detected in the fellow eye.

Conclusion

In the evaluation of 64 eyes of 32 patients, IOM statistically decreased DFA, similar to all publications in the literature. In our study, bilateral IOM reduced the mean DFA and DFA differences between both eyes in all patient groups. In secondary IOOA, unilateral IOM increased the DFA difference between the two eyes. Extortion decreased from 36 to 9 in the third month after bilateral IOM, and intorsion was seen in only 2. Unilateral IOM caused intorsion in 3 of 6 (50%) operated eyes by overcorrection in patients with secondary IOOA. Masked IOOA was detected in 3 of 11 (27.3%) patients who underwent unilateral IOM. When deciding on unilateral surgery, the possibility of increased DFA difference between both eyes, intorsion in the operated eye, and masked IOOA in the other eye should be considered.

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